

# Evaluation of repair methods for native defects on EUV masks

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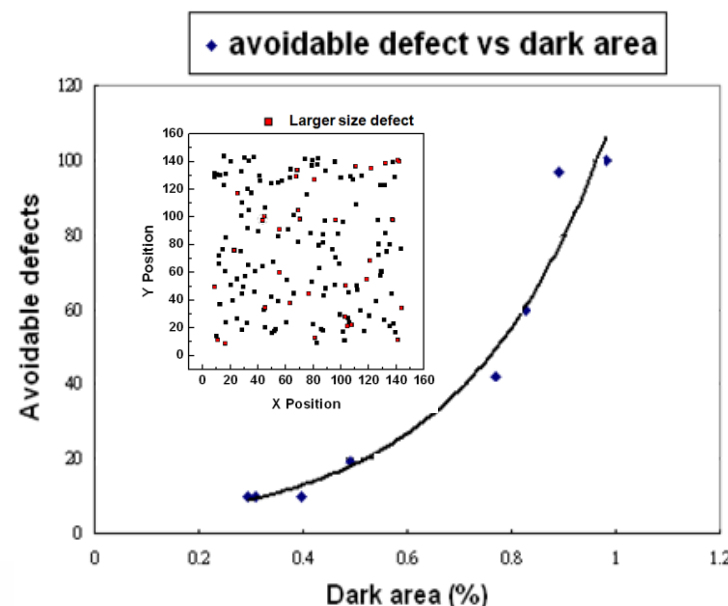
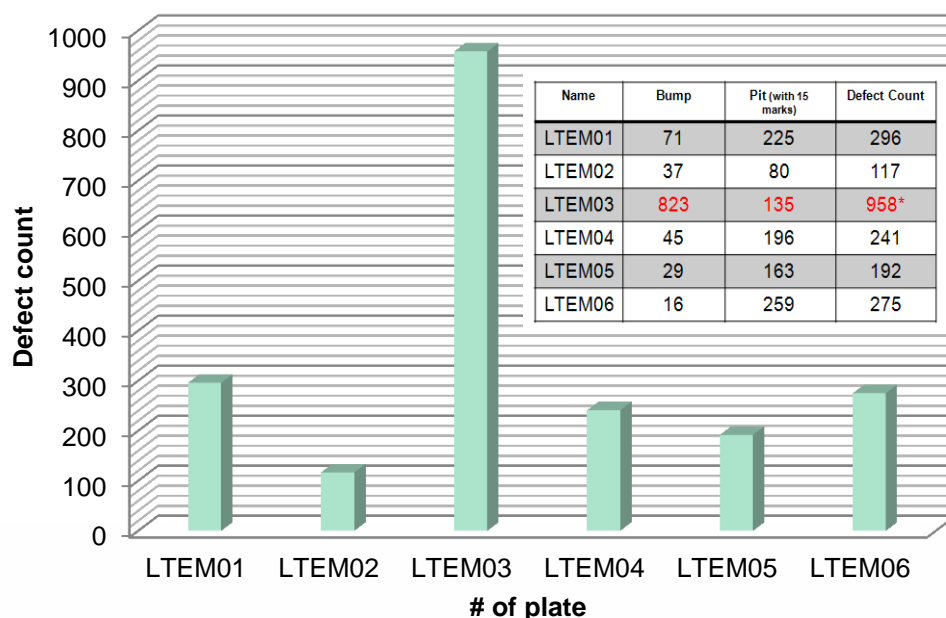
# Outline

- **Status of defect mitigation for native defects reduction**
- Challenges on native defects repair
- Overview of native defects repair strategies
- Potential approaches of native defects repair
- Summary

# EUV Blank Native Defects Reduction Status

● Native defects detected on current EUV mask blanks are still 10 times the numbers required for HVM and the effectiveness of the pattern shifting technique is limited. This means:

“EUV lithography must work with native defects present on the masks”



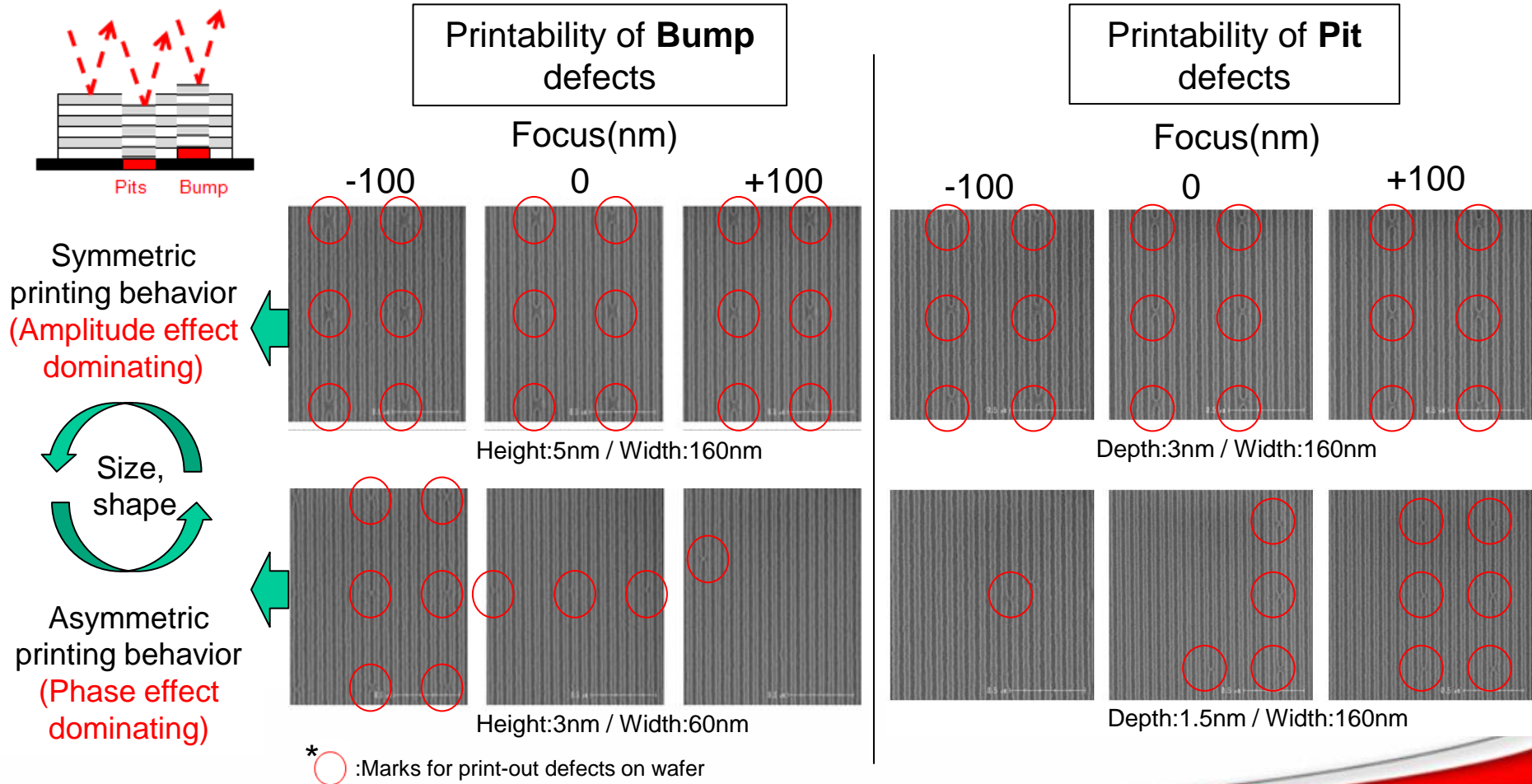
\*(Simulation results from random defects)

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# Inconsistent Printing Behavior of Native Defects

- Defect shapes appear to be a strong factor in printability because they affect both the phase and the amplitude in the light reflected from mask.



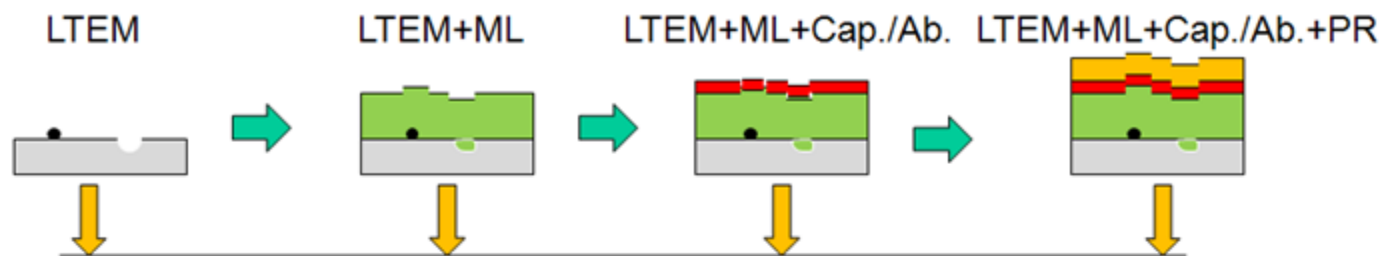
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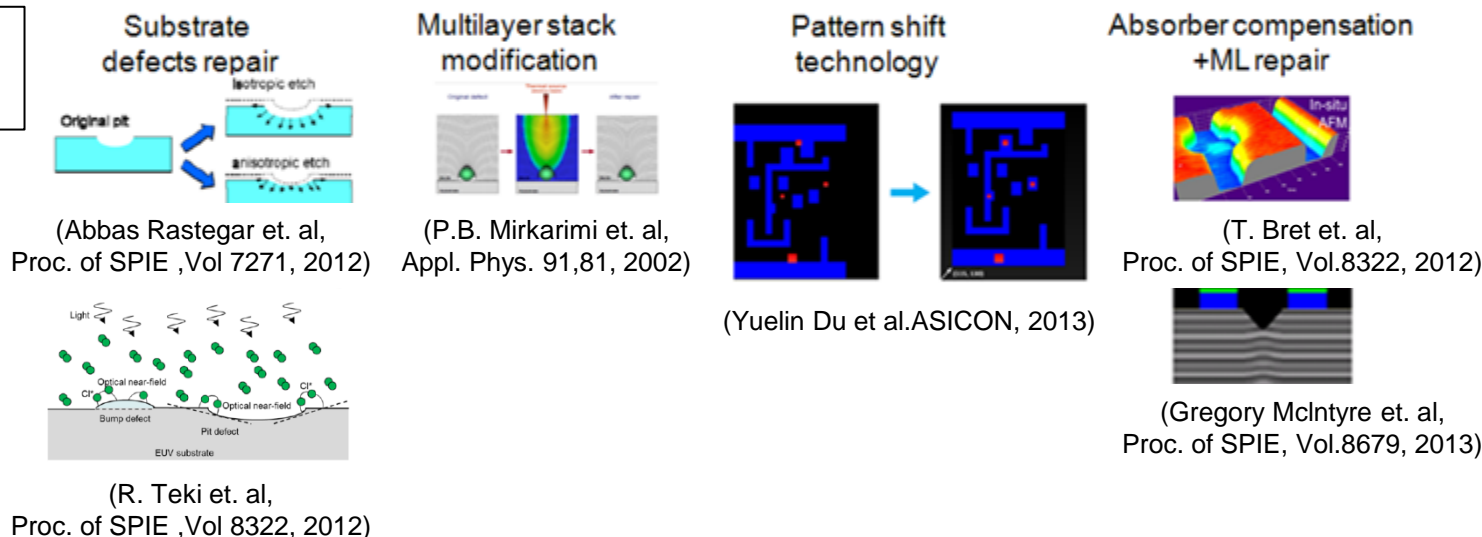
# Overview of EUV Mask Defect Repair Strategies

- Repair strategies on EUV mask defects have been proposed on every stage of the mask fabrication from substrates to patterned masks.

**Mask making processes:**



**Repair approaches:**



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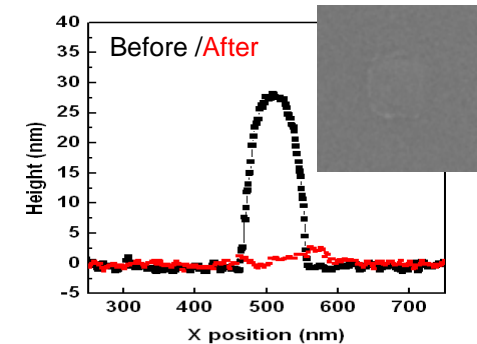
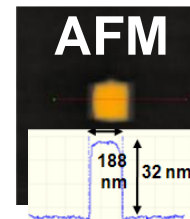
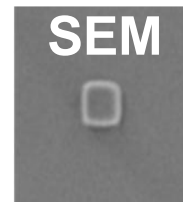
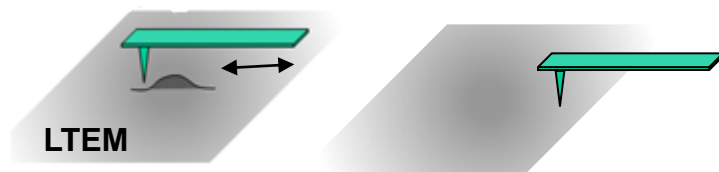
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# Potential Approaches of EUV Mask Defect Repair(1/3) -on LTEM Substrate

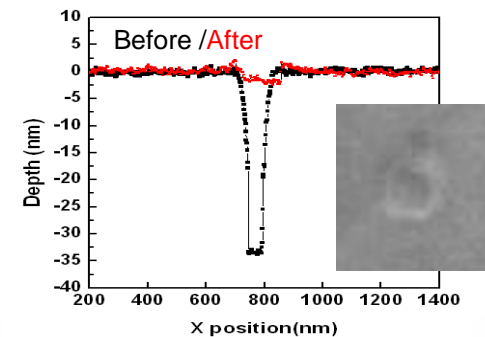
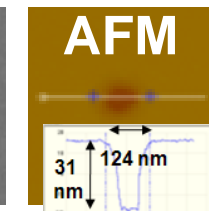
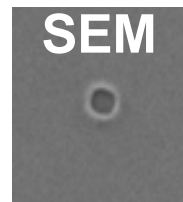
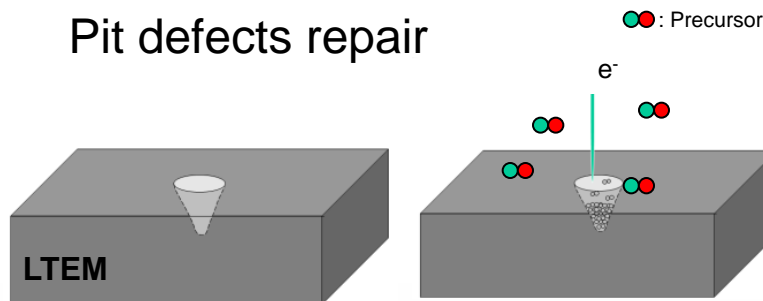
- Using nanomachining and electron-beam repair tool to trim the bump and pit defects of EUV LTEM

Bump defects repair



**Example: one LTEM bump defect repair result**

Pit defects repair



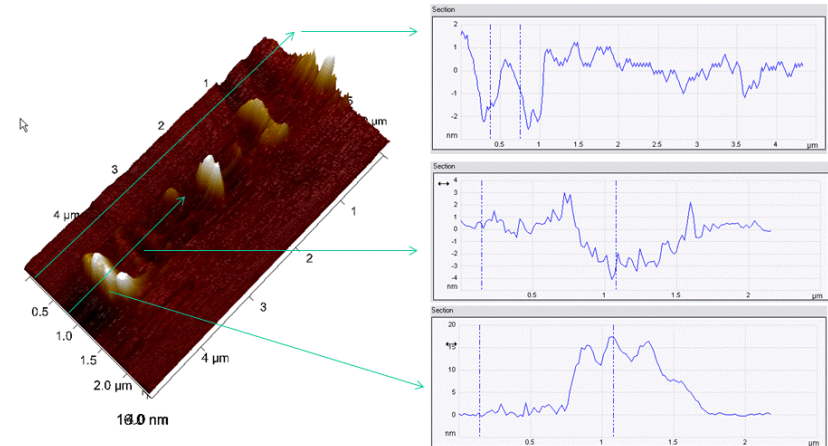
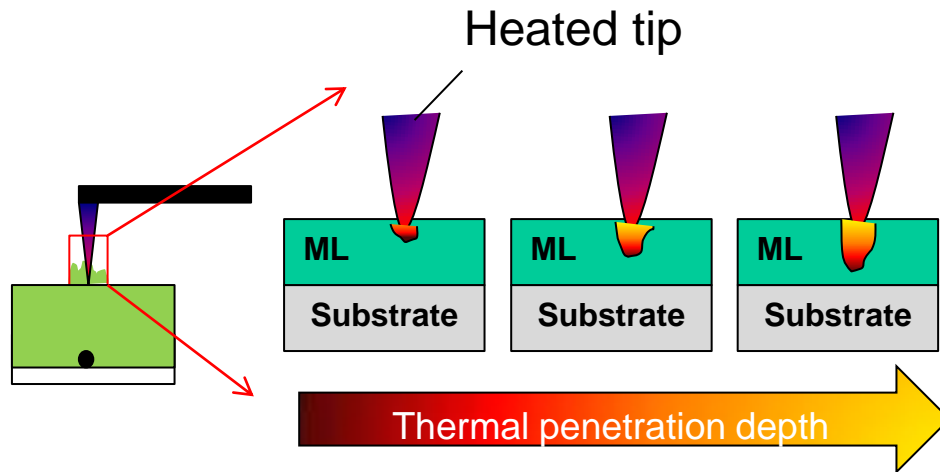
**Example: one LTEM pit defect repair result.**

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## Potential Approaches of EUV Mask Defect Repair(2/3) -on ML blank

- A specific heated probe is used to locally recover the distorted surface of EUV multilayer with underlying defects



**Example: multi-layer surface after treatment**

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# Potential Approaches of EUV Mask Defect Repair(3/3)

## - after mask patterning

- Inconsistent printing behavior of natives defects makes the detection and the control of repair more complex than conventional methods.

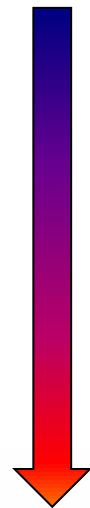
### *Native defects repaired with gradual compensation bias*

Mask images  
(after repair)

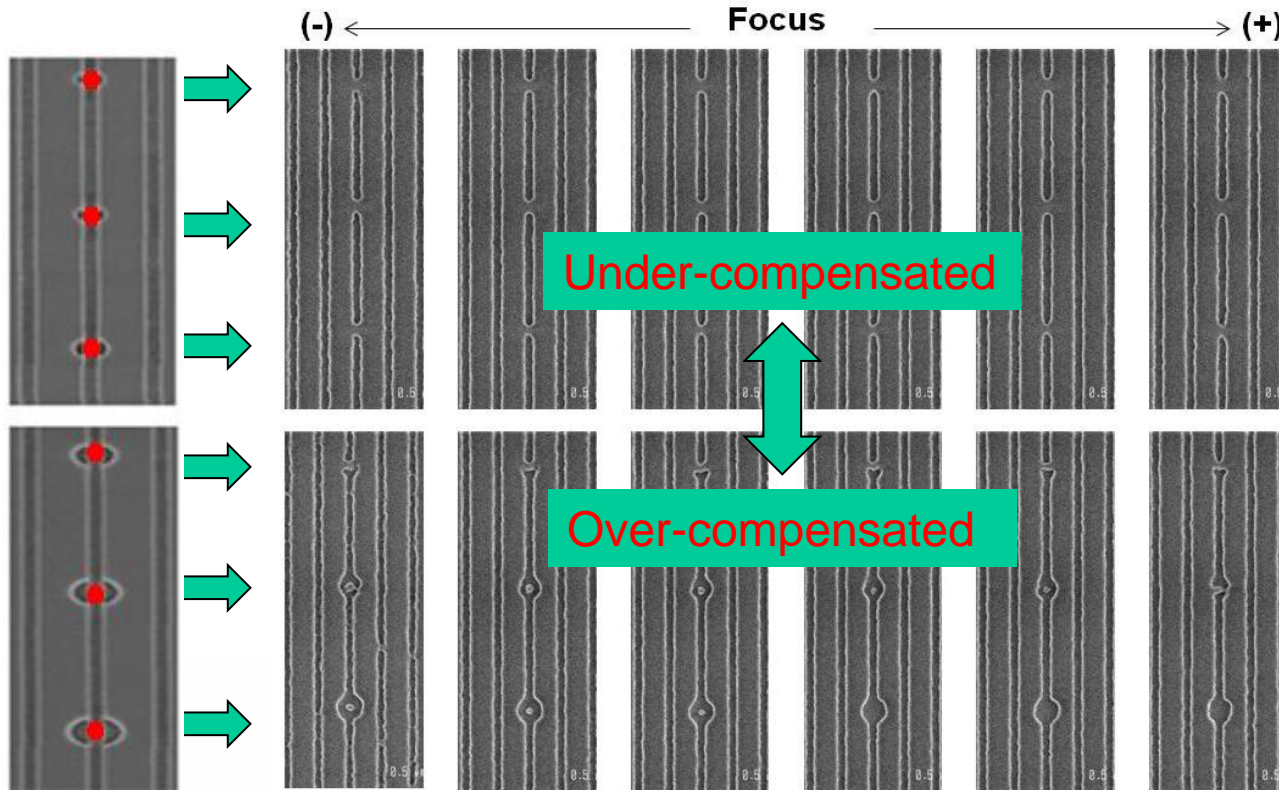
Wafer images of post-repair features  
(Exposed with focus meander, Step:50nm)

Ab. removal  
ratio:

Low



High



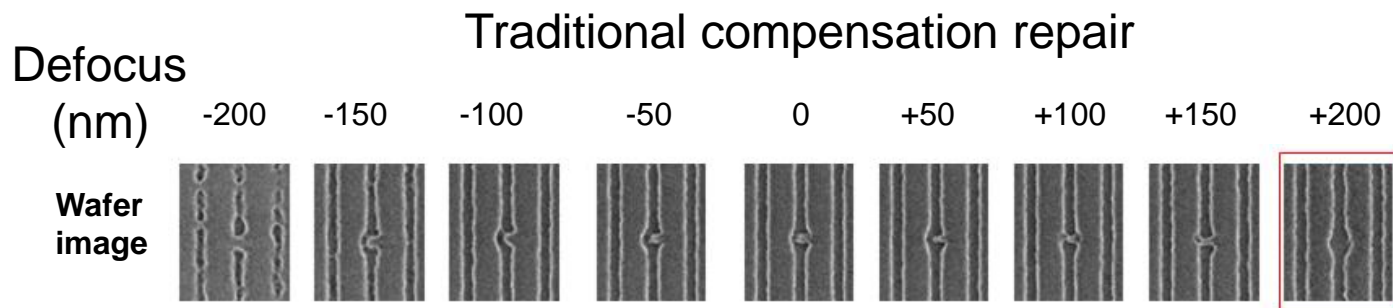
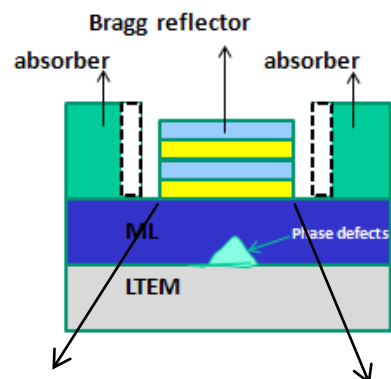
●:native defect



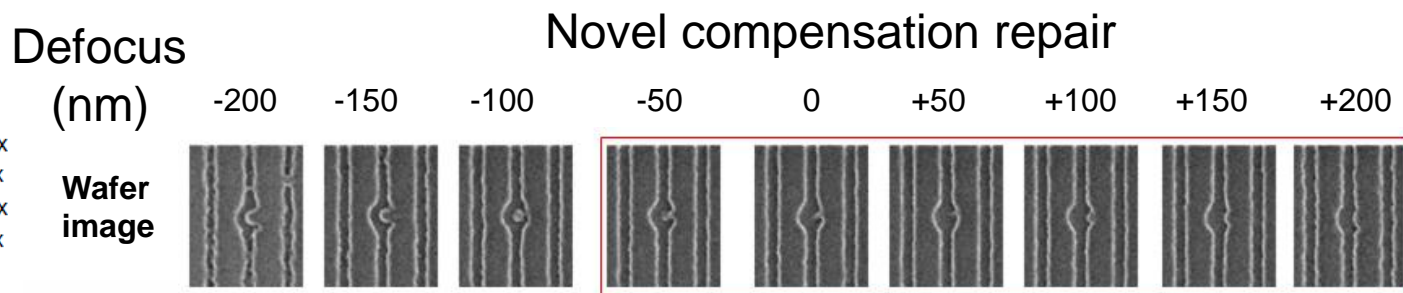
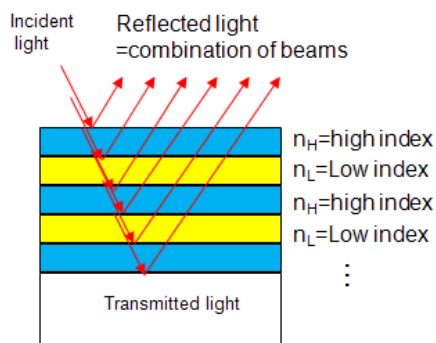
# Potential Approaches of EUV Mask Defect Repair(3/3)

- after mask patterning -cont'd

- Use of compensation in reflectivity and phase to form a more tolerable image on wafer



Bridge-free window < 50nm



Bridge-free window > 200nm



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- ✓ **Current densities of native defects on EUV mask blanks are still higher than required for high-volume production. In order to yield defect-free masks, repair capability is needed for the reduction of native defects.**
- ✓ **Inconsistent printing behavior of native defects due to loss of reflectivity and change of phase has affected and influenced the whole EUV mask repair strategies.**
- ✓ **We have investigated a method for reducing the number of native defects on LTEM substrate by local polishing and proved the feasibility of multilayer modification repair using a thermal probe.**
- ✓ **A more effective compensation method has been investigated to reduce the phase difference and minimize the loss of reflectivity between the defect-free and phase-defect regions .**

## Acknowledgements

- ✓ The work presented today is the result of hard work and dedication of EUV mask and process teams at TSMC.
- ✓ Special thanks go to:
  - **Kevin Huang** and **Alex Chen** for technical support in nanomachining.